NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

Know the Earth... Show the Way... Understand the World

NGA's Relationship With GPS

Presented to the PNT Advisory Board 14-15 August 2012

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NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

Know the Earth... Show the Way... Understand the World

NGA MISSION





To provide timely, relevant, and accurate GEOINT in support of national security.

NGA is the lead federal agency responsible for Geospatial Intelligence – or GEOINT

Approved for Public Release – NGA Case #12-003

What *is* GEOINT?

- **Where am I?**
- **Where are the natural and man-made structures? How do I navigate them?**
- **What does the area look like now? What activities are taking place there?**
- **What might it look like after an event?**

NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

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OUR HISTORY

AMERICAN Revolution | CIVIL WAR | WWII | COLD WAR | NIMA | NGA

Surveying

Balloons

Aerial Imagery

Satellites

1996 Imagery & Mapping

2003

Geospatial Intelligence

Approved for Public Release – NGA Case #12-003

TYPES OF DATA

Remotely Sensed Data

Panchromatic

Infrared

Radar

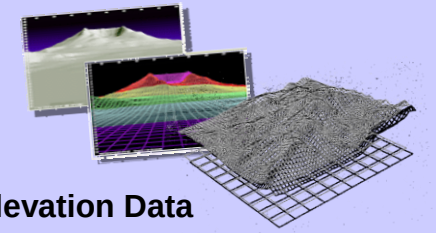
Multispectral

Hyperspectral

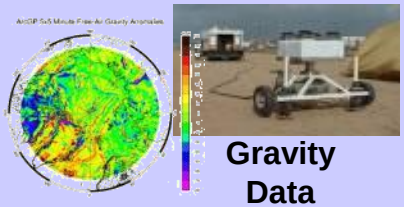
Physical Geography

GPS Tracking and Coordinate Systems

Geology

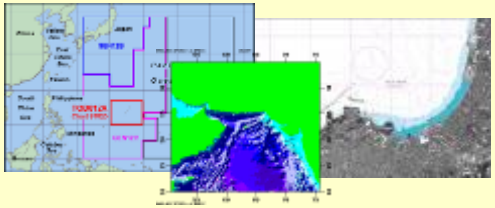


Elevation Data



Gravity Data

Land Cover and Cultural Data



Hydrographic Data

Vegetation

Boundaries, Transportation and Infrastructure

Open Source

VARIETY OF PLATFORMS

Classified Systems

Commercial Satellites

GeoEye

DIGITALGLOBE

Predator

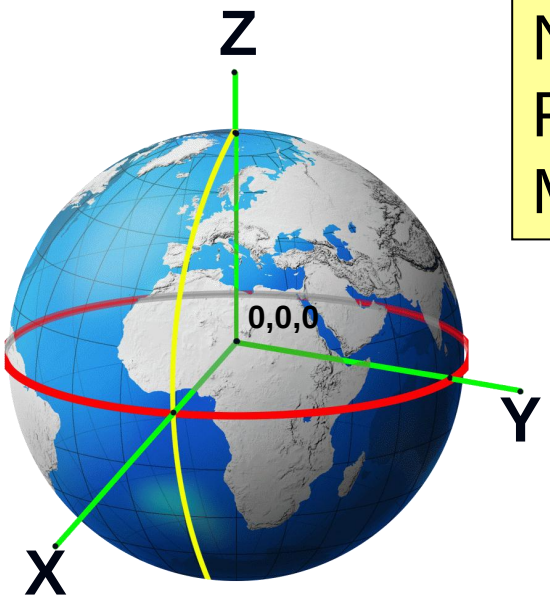
Global Hawk

Constant Hawk

U-2

Airborne

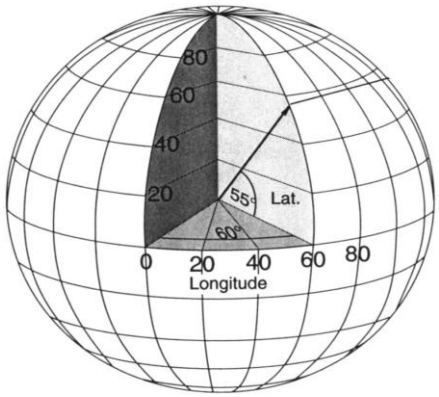
World Geodetic System 1984

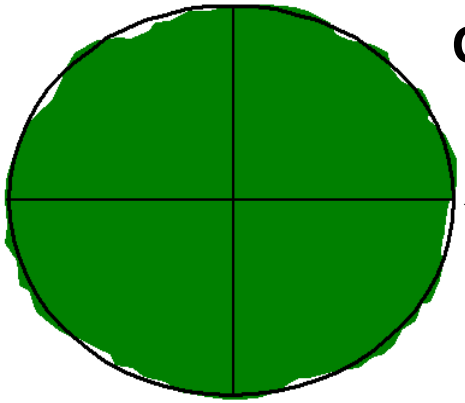


NGA –Developed the Global Reference Frame and Geophysical Models for all Modern Geospatial Information

Global Reference Frame Accuracy

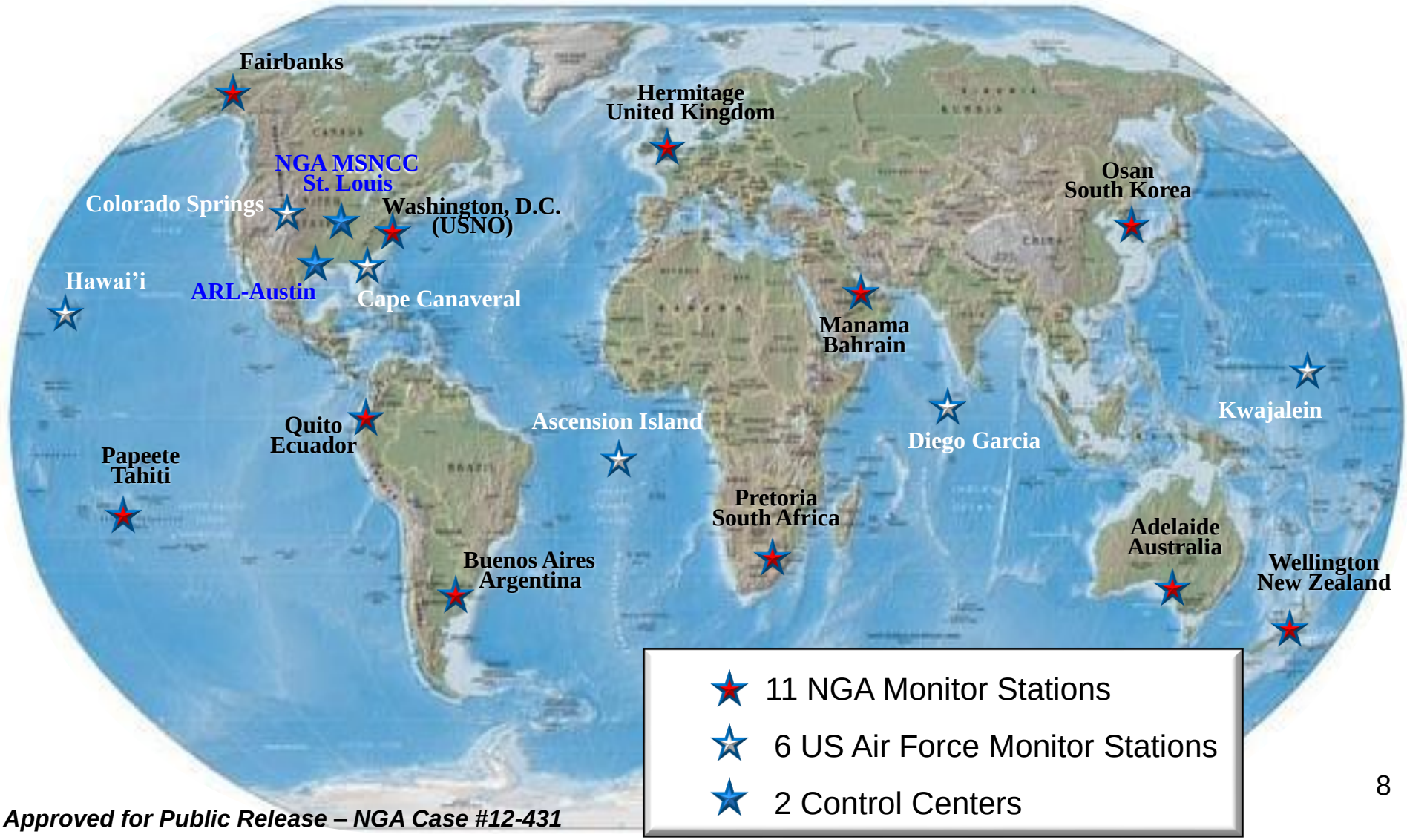
Transit (1 - 2 m)	Jan 1987
G730 (10 cm)	Jun 1994
G873 (5 cm)	Jun 1997
G1150 (1-2 cm)	Jan 2002
G1674 (1 cm)	**Feb 2012**





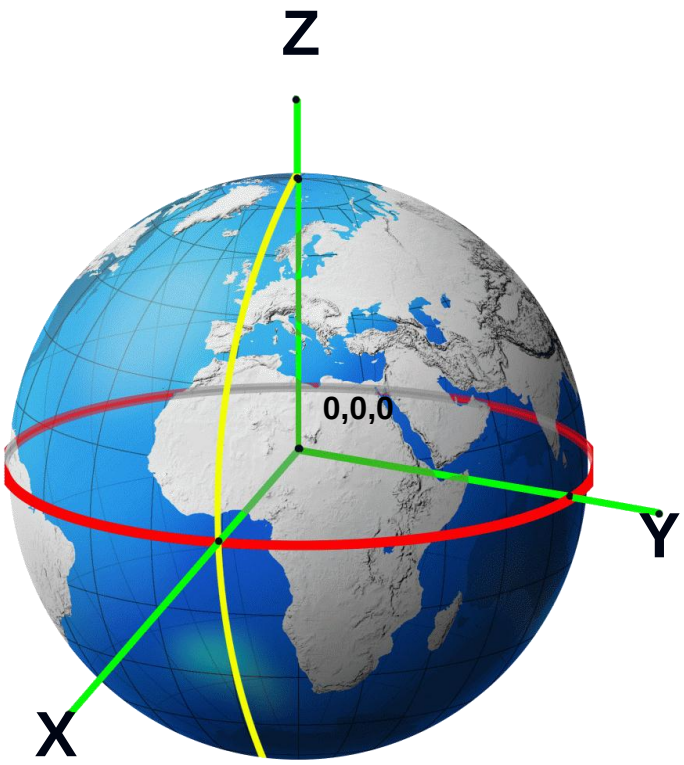
The geoid is used as a surrogate for mean sea level, the vertical datum for traditional ‘elevations’

DoD GPS Ground Station Network

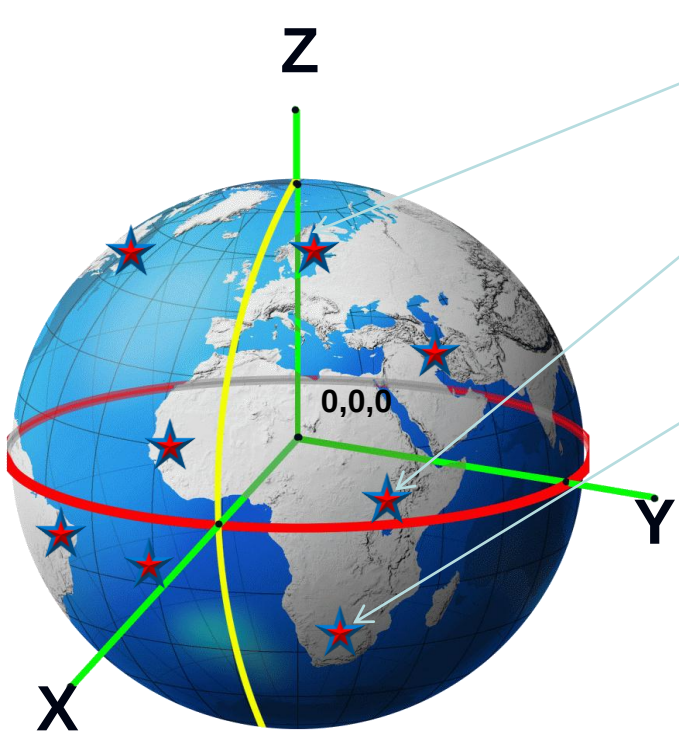


The 'Realization' of an Earth-Centered, Earth-Fixed Global Reference Frame

Definition



Realization



X=-1248597.295m
Y=-4819433.239m
Z= 3976500.175m

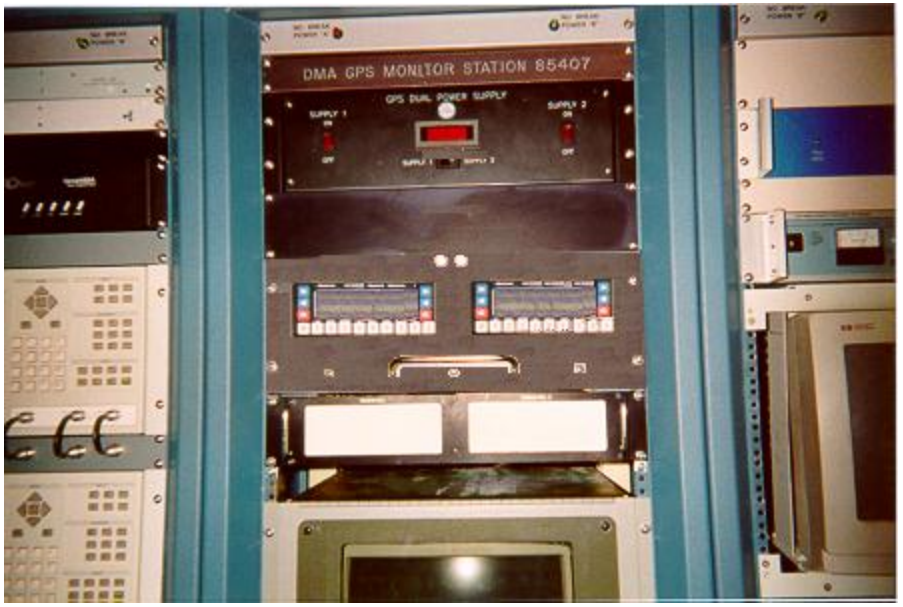
X= 6118524.122m
Y=-1572350.853m
Z= -876463.990m

X= 1916197.142m
Y= 6029999.007m
Z= -801737.366m

. . .

NGA also provides Earth-orientation parameter predictions to the GPS OCS on a routine basis

NGA GPS Tracking Station at the US Naval Observatory



The NGA GPS Tracking Station at USNO uses a frequency standard tied to UTC(USNO)

NGA Monitoring Station Receivers

- Texas Instruments TI 4100
  Dec 1985 - Jan 1994
  L1 C/A, L1/L2 P
  4 SVs, No A-S capability

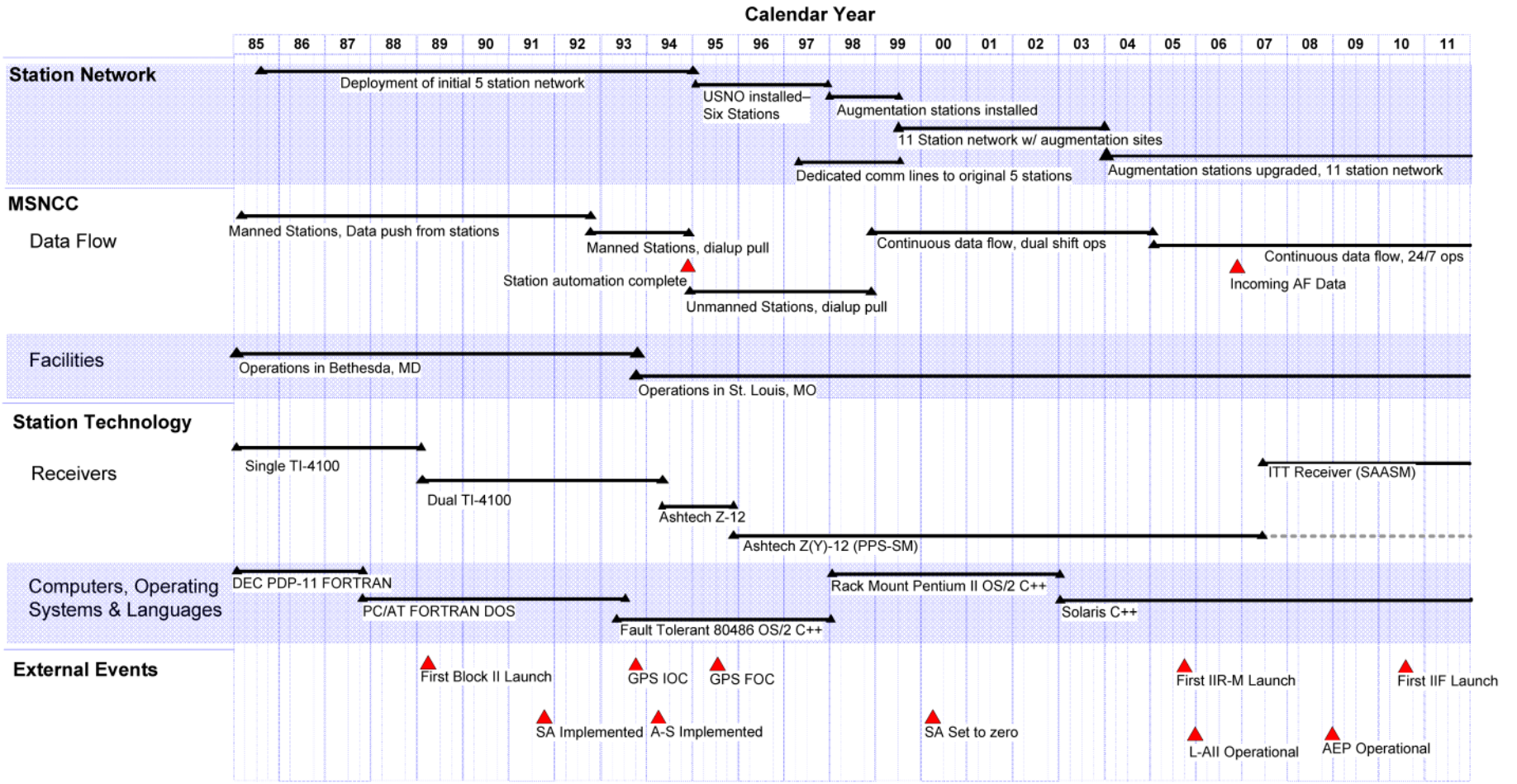
- Ashtech Z(Y)-12
  Jan 1994 – 2010
  L1 C/A, L1/L2 P(Y)
  12 SVs, PPS-SM

- ITT MSN SAASM Receiver
  2010 – current
  L1 C/A, L2C, L1/L2 P(Y)
  12 SVs, SAASM

Current NGA Monitor Station Technology

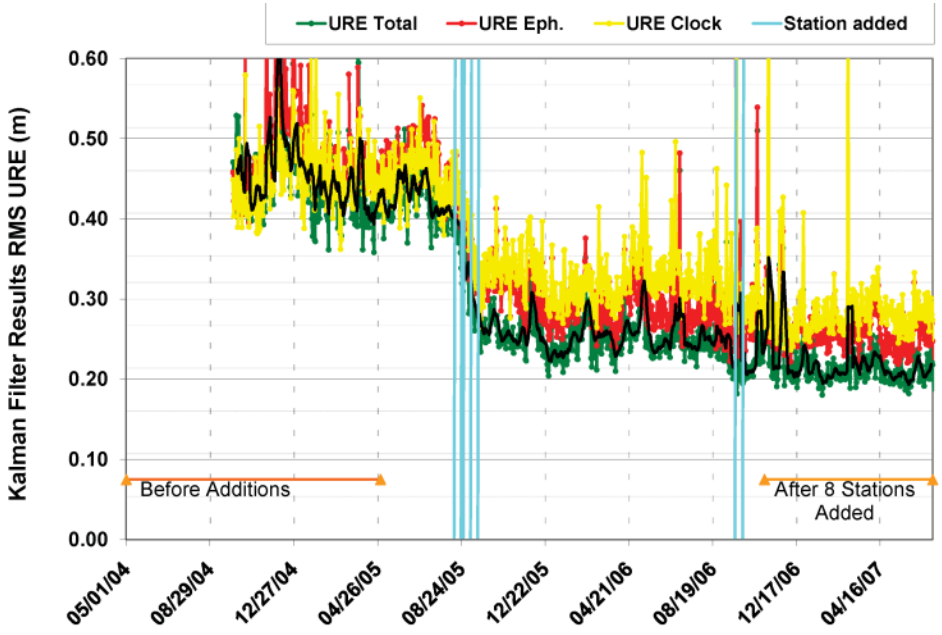
- ITT SAASM Receiver
  (above, upper left rack),
- SUN computer,
  (center right)
- HP-5071A Frequency Standard.
  (upper right rack)

The Timeline

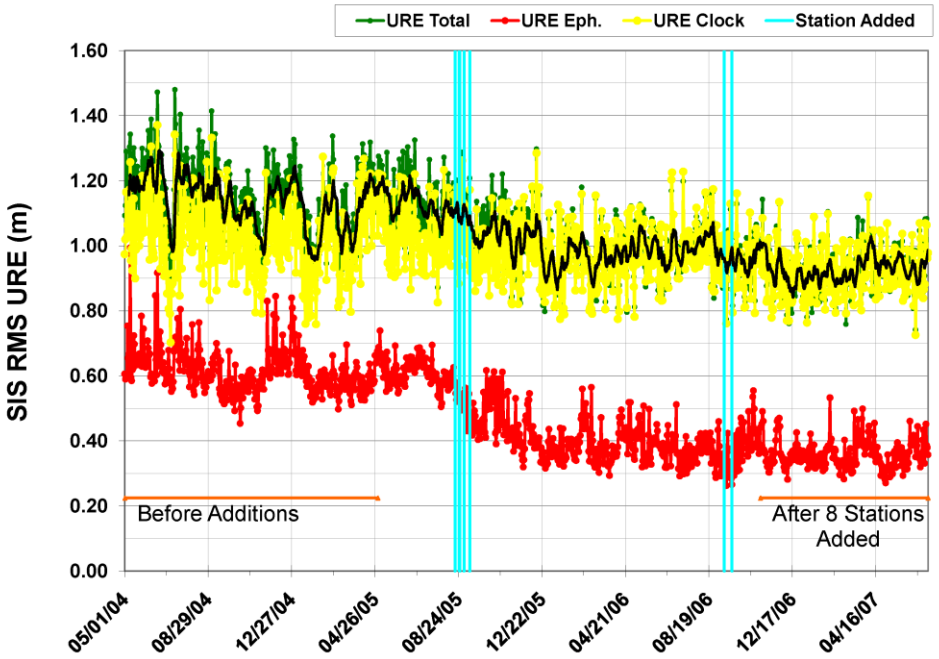


NGA Monitor Station Data Begins to Feed OCS

Impact on User Range Error (URE)



- Zero Age of Data URE
- Additional stations results in 51% improvement.



SIS RMS URE represents:

- Ephemeris and clock performance delivered to the user after the orbit predicted forward in time and broadcast from the SVs.

- Improvement is more modest (about 19%)

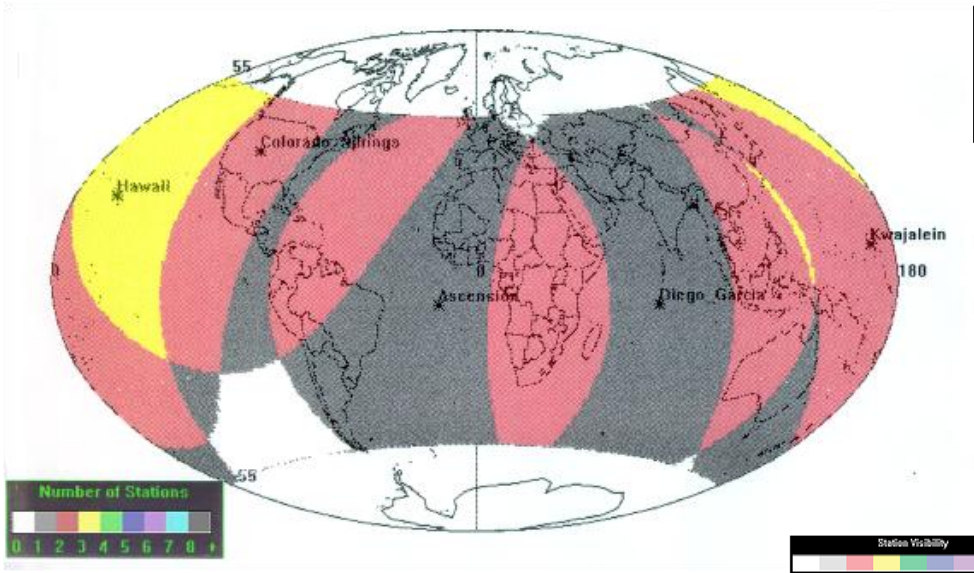
NGA Network


NGA Network Control Center

Fairbanks
Hermitage
United Kingdom
Washington, D.C.
(USNO)
Colorado Springs
(GPS Master
Control Station)
Cape Canaveral
Hawaii
Quito
Ecuador
Papeete
Tahiti
Ascension Island
Pretoria
South Africa
Buenos Aires
Argentina
Manama
Bahrain
Osan
Korea
Diego Garcia
Kwajalein
Adelaide
Australia
Wellington
New Zealand

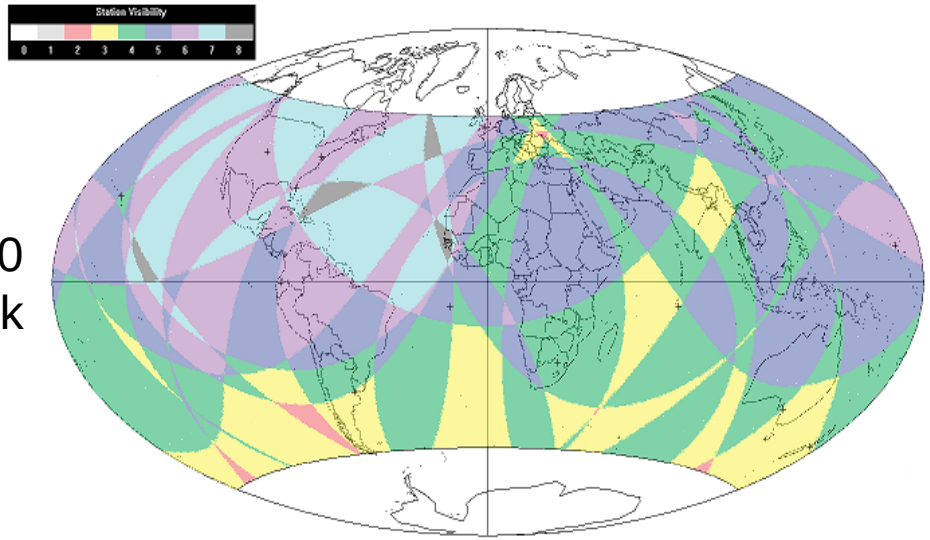
NGA Monitor Stations
OCS Monitor Stations

Impact on Satellite Visibility



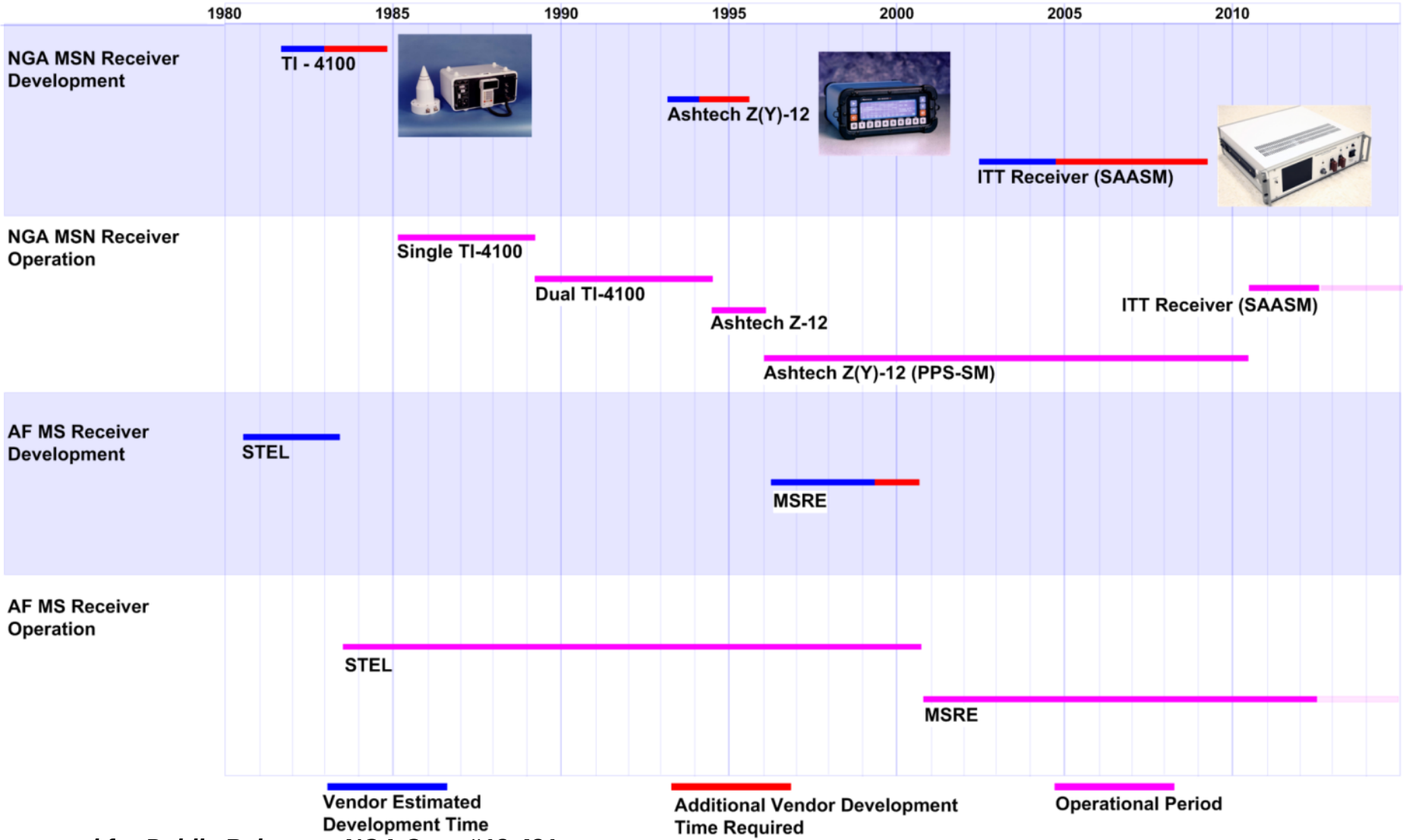
Co-visibility plotted along ground track projection of SV orbit

Co-visibility plot for five original OCS monitor stations



Co-visibility plot for 6 OCS + 10 NGA station network

Monitor Station Development/Deployment



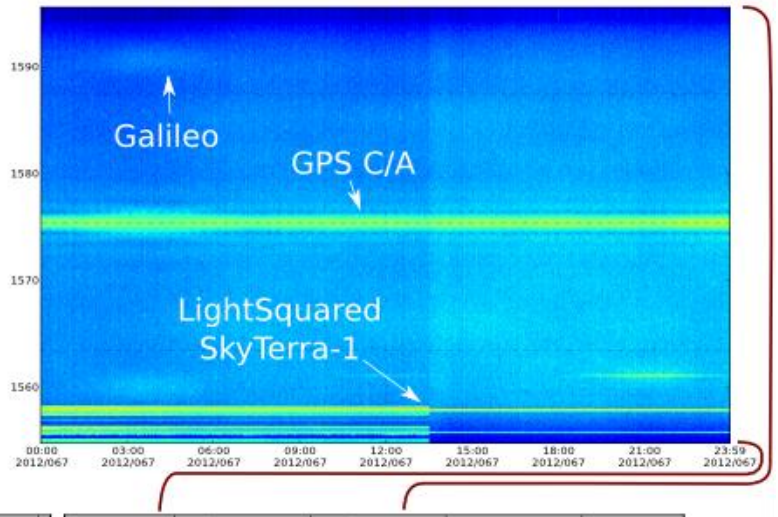
High Rate Tracking Receiver (HRTR)

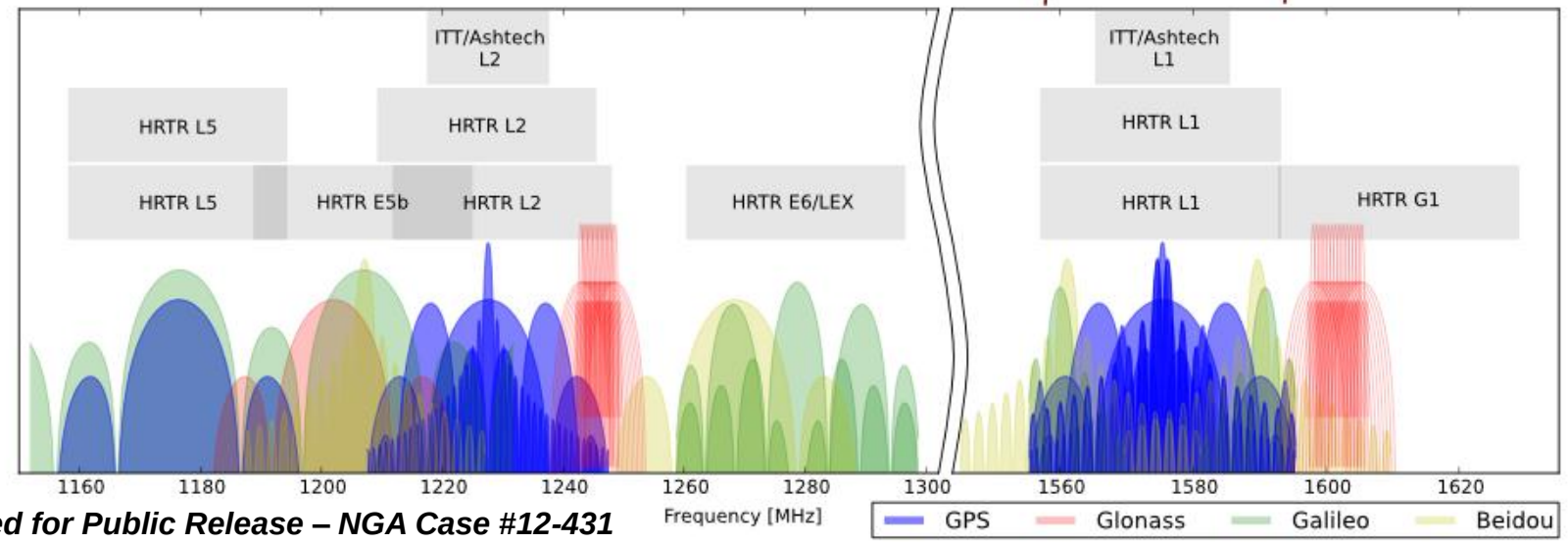
- A software-defined receiver architecture
  - Designed to JMSRE requirements and interfaces
  - IP Licensed such that government pays for development of features *once* instead of for each procurement
- Digitizing Front End (DFE)
  - Directly samples entire L-band
  - At 2 gigasamples/s with digital downconversion
- Baseband processing
  - Tracks GNSS signals in real-time using FPGAs
- Software reconfigurable
  - Supports new frequency bands and new signals via remote firmware update
  - Supports both traditional observations and detailed signal observations
- HRTRs deployed to four NGA sites in 2011

HRTR at NGA Station in Alaska, deployed in 2011

Spectrum Awareness

- L-Band spectrum is heavily used
- 100+ SVs expected for GNSS alone
- High Rate Tracking Receiver (HRTR) well suited to globally monitor ICD compliance and spectral incursions





Contrast Between MS Receivers and Typical GNSS Navigation Receivers

- Requirements of navigation receivers not relevant to monitoring
- Requirements of navigation receivers in conflict with monitoring
- Track signals "outside the envelope" of the specifications
- MS collect full compliment of codes and carriers
- Long-term continuous operation
- Different handling of signal anomalies
- Focus on providing low level raw measures of highest quality rather than accurate PVT solutions

Challenges Faced by Modernization

Develop a receiver that:

- Can track all required signals
- Supports expanded constellation (30+)
- Supports development, test and SV initialization work
- Supports payload anomaly recovery actions
- Supports tighter accuracy requirements in future
- Meets security requirements
- Is sustainable and maintainable over the long haul
- Meets schedule constraints for development and deployment

Summary

- NGA Monitor Stations directly support the operation of the GPS constellation
- Monitor Station Receivers
  - Have unique capabilities
  - Require long timelines to develop, test and deploy
  - Are critical for the operation and performance of the constellation
- GPS is critical for virtually ALL modern Geospatial data collected within NGA and the National System for Geospatial Intelligence (NSG)

NSG Members	NSG Partners
DNI, DIA, NRO, CIA, NSA, CG, DOS, DOE, DHS, DEA, FBI, OUSD(I), DOJ, Services, Joint Staff, COCOMS	USACE, DOA, DOC, DHS, DOI, DOT, EPA, FEMA, NASA, NSF, DISA, DLA, CAC, Australia, Canada, UK, NZ, Industry, Academia, Intl. Entities

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